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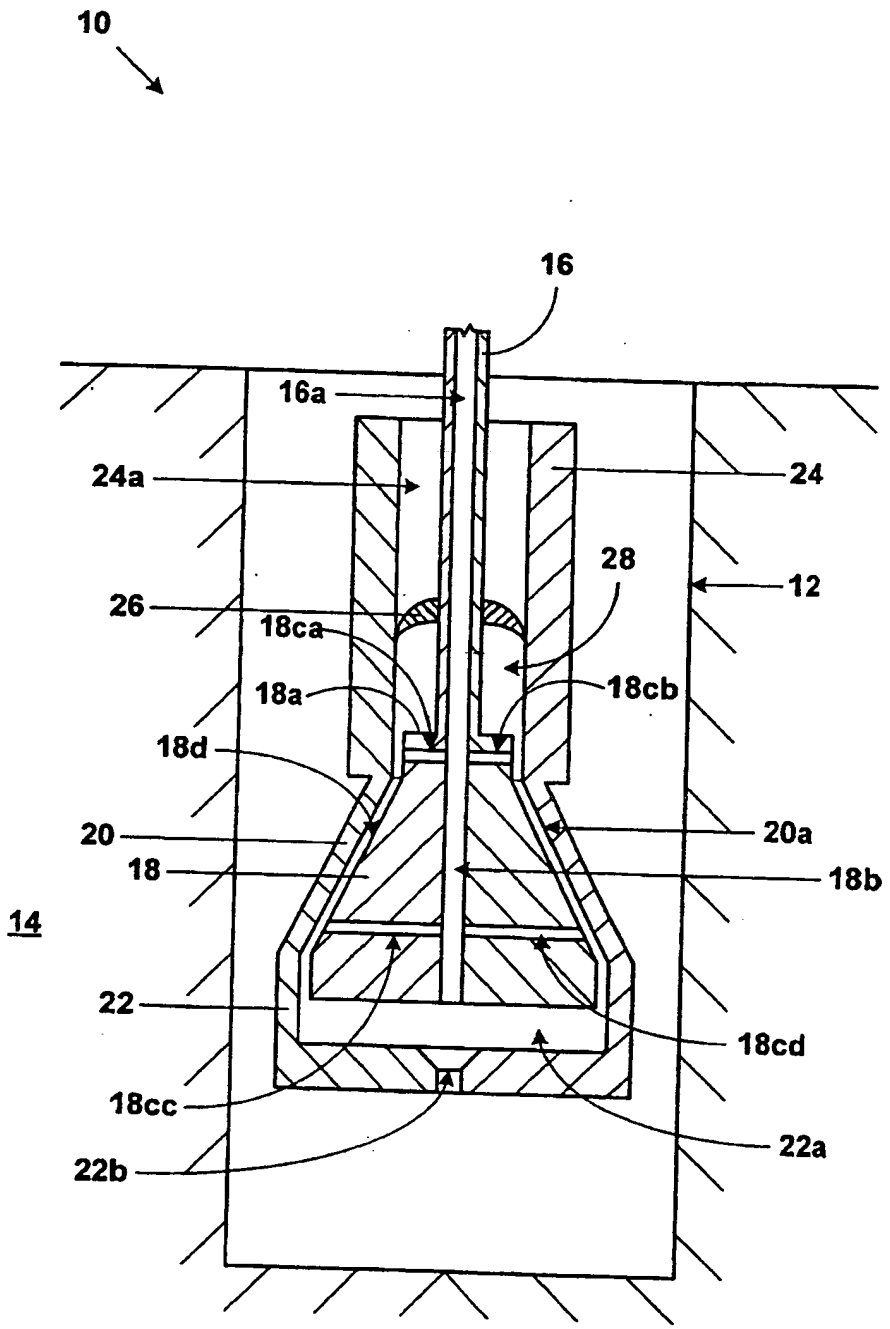
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24a
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28
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26
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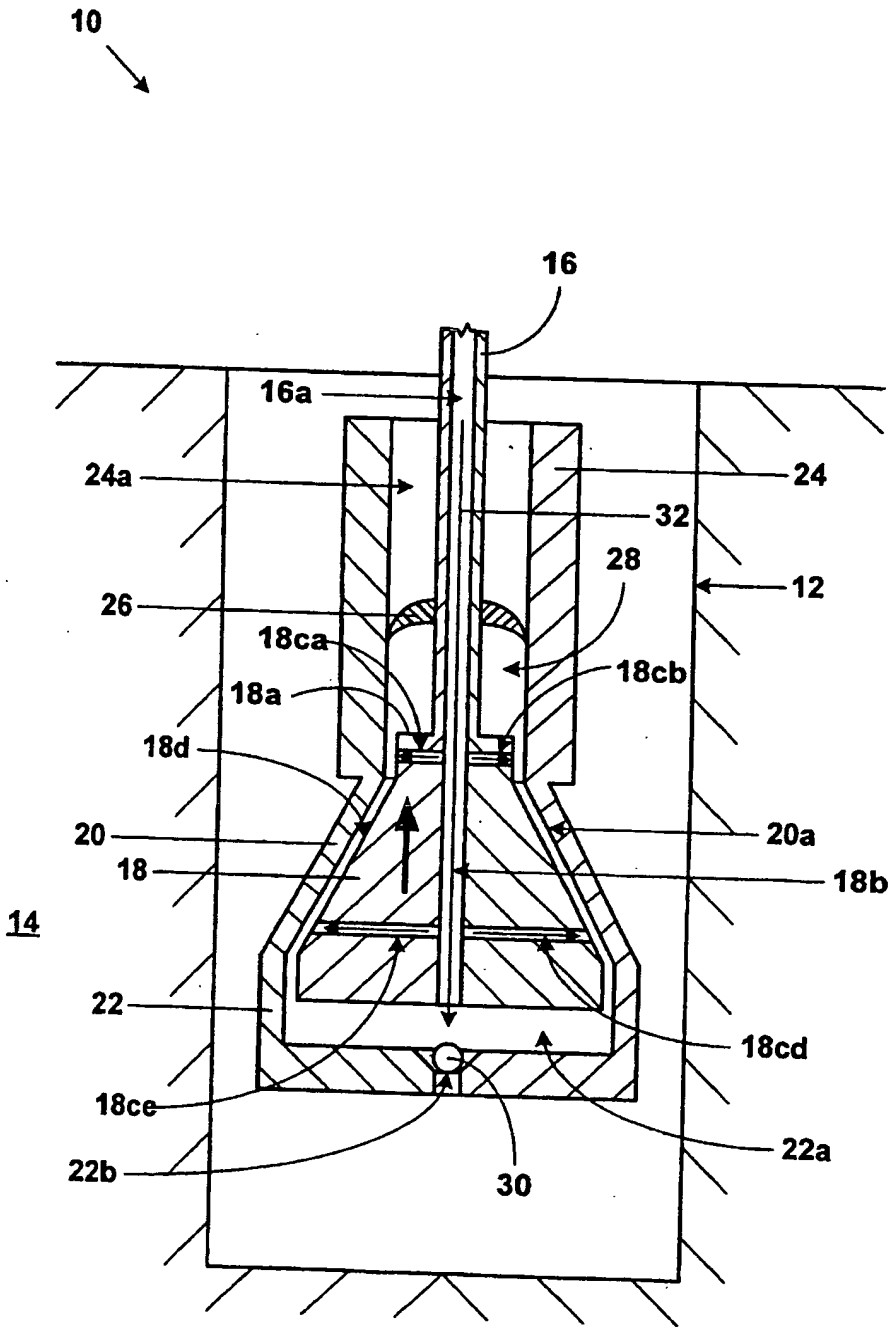
18cb
18a
18d
20
20a
18
18b
14
22
18cd
18cc
22a
22b

Fig. 1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22b
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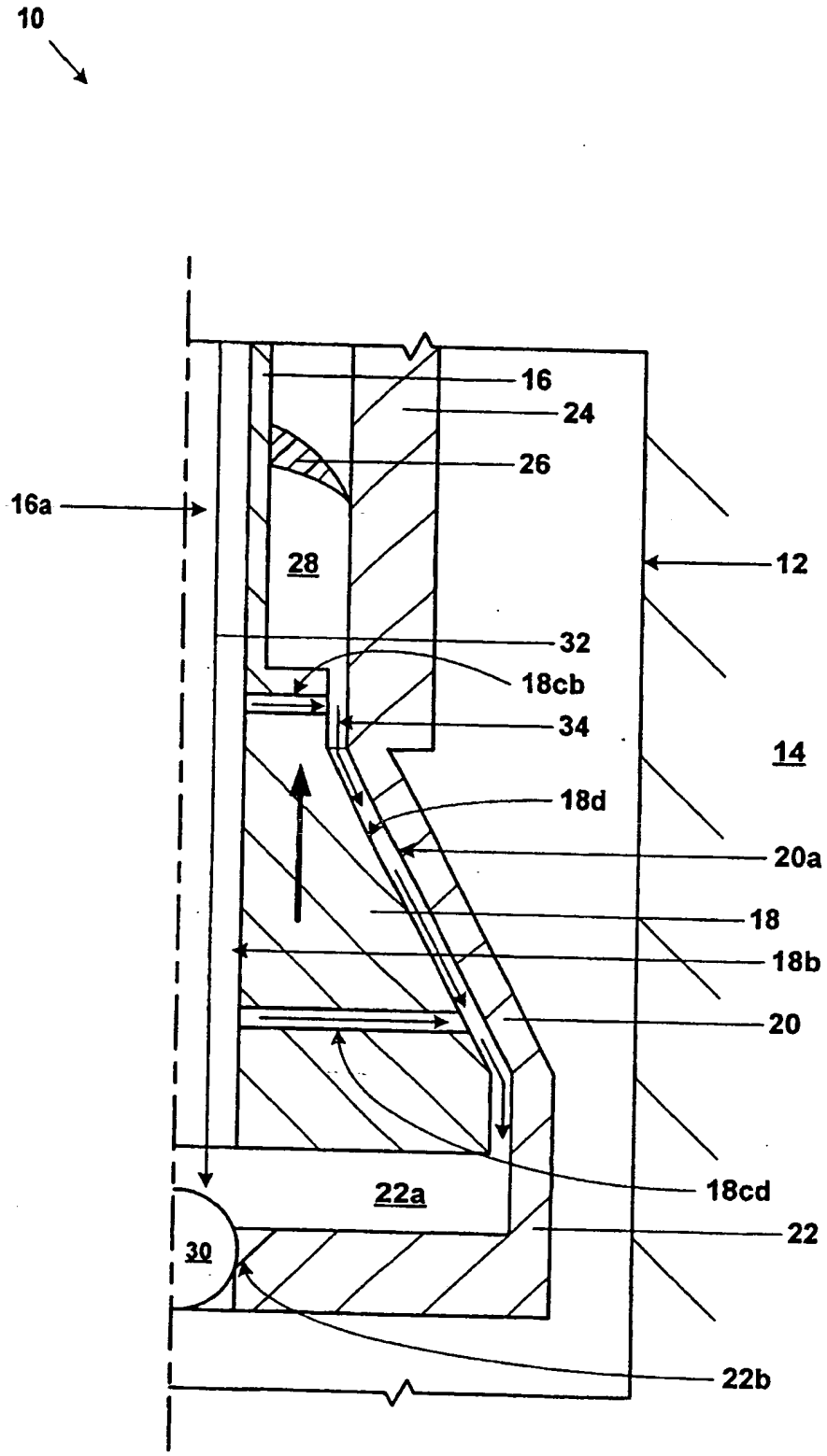
Fig. 2a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16a
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18b
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22a
22
30
22b

Fig. 2b

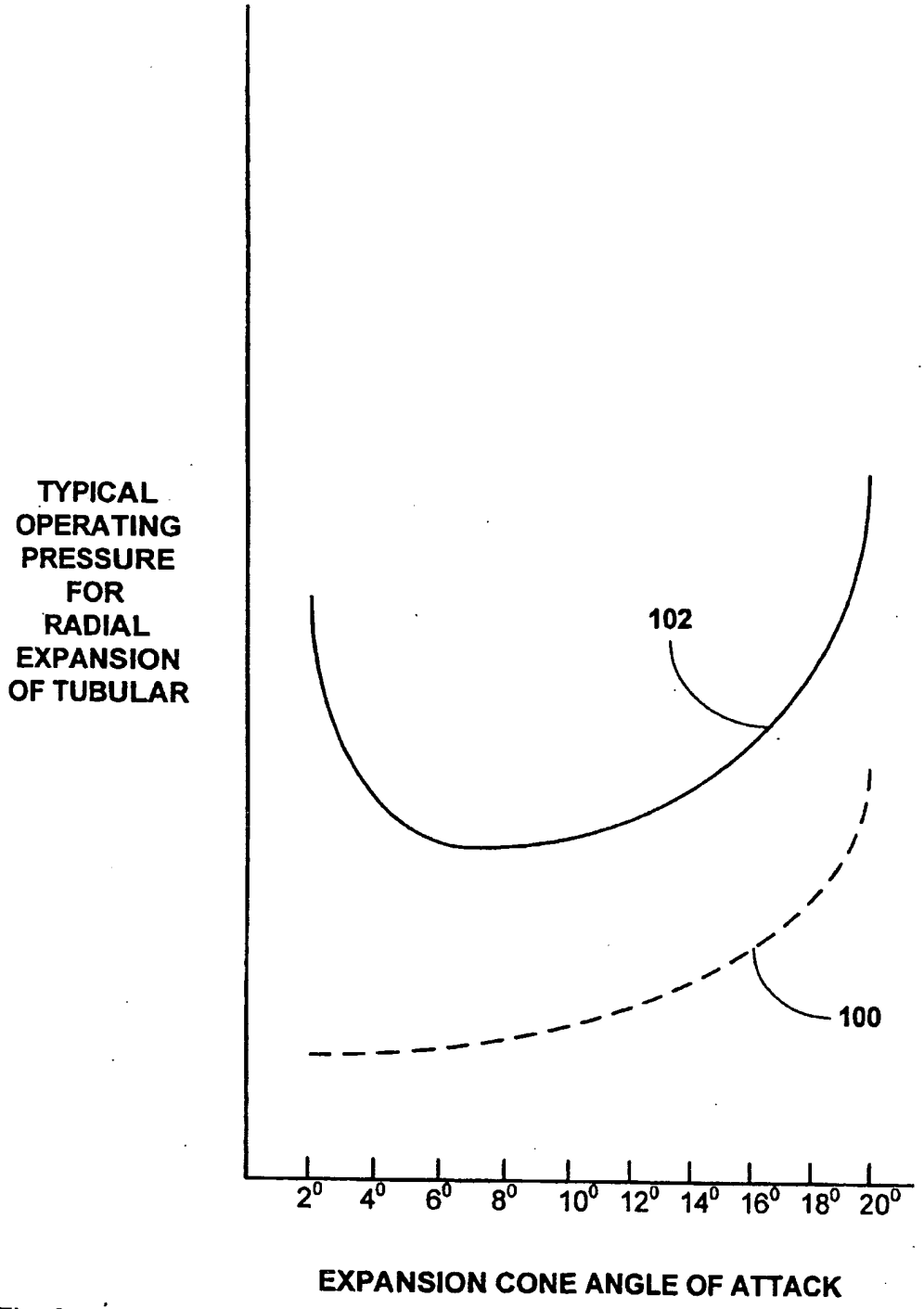
TYPICAL OPERATING PRESSURE FOR RADIAL EXPANSION OF TUBULAR
102
100
2^0 4^0 6^0 8^0 10^0 12^0 14^0 16^0 18^0 20^0
EXPANSION CONE ANGLE OF ATTACK

Fig. 3

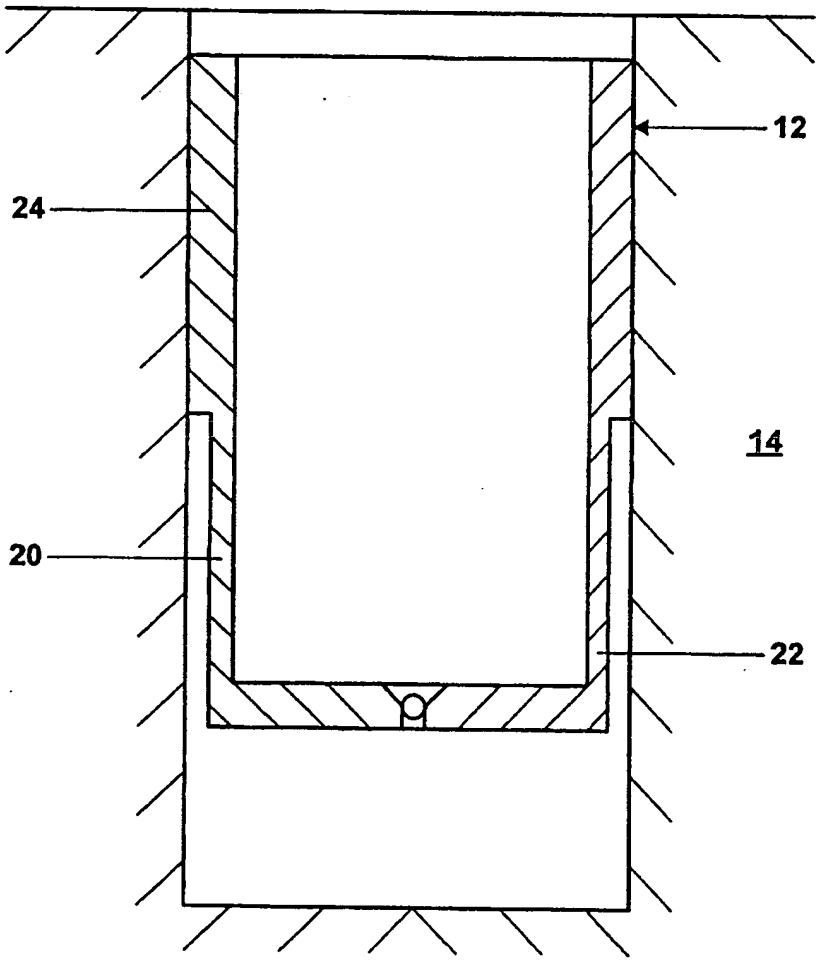

Fig. 4

SYSTEM FOR RADIALLY EXPANDING A TUBULAR MEMBER

Cross Reference To Related Applications

[001] The present application is the National Stage patent application for PCT patent application serial number PCT/US2003/015020, attorney docket number 25791.90.02, filed on 05/12/2003, which claimed the benefit of the filing dates of (1) U.S. provisional patent application serial no. 60/391,703 attorney docket no 25791.90, filed on 6/26/2002, the disclosures of which are incorporated herein by reference.

[002] The present application is a continuation-in-part of U.S. utility patent application serial number 10/418,687, attorney docket number 25791.228, filed on 4/18/2003, which was a continuation of U.S. utility patent application serial number 09/852,026, attorney docket no. 25791.56, filed on 5/9/2001, which was a division of U.S. utility patent application serial number 09/454,139, attorney docket no. 25791.3.02, filed on 12/3/1999, which claimed the benefit of the filing date of U.S. provisional patent application serial number 60/111,293, attorney docket number 25791.3, filed on 12/7/1998.

[003] The present application is related to the following: (1) U.S. patent application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, (2) U.S. patent application serial no. 09/510,913, attorney docket no. 25791.7.02, filed on 2/23/2000, (3) U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, (4) U.S. patent no. 6,328,113, (5) U.S. patent application serial no. 09/523,460, attorney docket no. 25791.11.02, filed on 3/10/2000, (6) U.S. patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, (7) U.S. patent application serial no. 09/511,941, attorney docket no. 25791.16.02, filed on 2/24/2000, (8) U.S. patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, (9) U.S. patent application serial no. 09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, (10) PCT patent application serial no. PCT/US00/18635, attorney docket no. 25791.25.02, filed on 7/9/2000, (11) U.S. provisional patent application serial no. 60/162,671, attorney docket no. 25791.27, filed on 11/1/1999, (12) U.S. provisional patent application serial no. 60/154,047, attorney docket no. 25791.29, filed on 9/16/1999, (13) U.S. provisional patent application serial no. 60/159,082, attorney docket no. 25791.34, filed on 10/12/1999, (14) U.S. provisional patent application serial no. 60/159,039, attorney docket no. 25791.36, filed on 10/12/1999, (15) U.S. provisional patent application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (16) U.S. provisional patent application serial no. 60/212,359, attorney docket no. 25791.38, filed on 6/19/2000, (17) U.S. provisional patent application serial no. 60/165,228, attorney docket no. 25791.39, filed on 11/12/1999, (18) U.S. provisional patent application serial no. 60/221,443, attorney docket no. 25791.45, filed on 7/28/2000, (19) U.S. provisional patent application serial no. 60/221,645, attorney docket no. 25791.46, filed on 7/28/2000, (20) U.S. provisional patent

lication serial no. 60/233,638, attorney docket no. 25791.47, filed on 9/18/2000, (21) U.S. provisional patent application serial no. 60/237,334, attorney docket no. 25791.48, filed on 10/2/2000, (22) U.S. provisional patent application serial no. 60/270,007, attorney docket no. 25791.50, filed on 2/20/2001, (23) U.S. provisional patent application serial no. 60/262,434, attorney docket no. 25791.51, filed on 1/17/2001, (24) U.S, provisional patent application serial no. 60/259,486, attorney docket no. 25791.52, filed on 1/3/2001, (25) U.S. provisional patent application serial no. 60/303,740, attorney docket no. 25791.61, filed on 7/6/2001, (26) U.S. provisional patent application serial no. 60/313,453, attorney docket no. 25791.59, filed on 8/20/2001, (27) U.S. provisional patent application serial no. 60/317,985, attorney docket no. 25791.67, filed on 9/6/2001, (28) U.S. provisional patent application serial no. 60/3318,386, attorney docket no. 25791.67.02, filed on 9/10/2001, (29) U.S. utility patent application serial no. 09/969,922, attorney docket no. 25791.69, filed on 10/3/2001, (30) U.S. utility patent application serial no. 10/016,467, attorney docket no. 25791.70, filed on 12/10/2001, (31) U.S. provisional patent application serial no. 60/343,674, attorney docket no. 25791.68, filed on 12/27/2001, (32) U.S. provisional patent application serial no. 60/346,309, attorney docket no 25791.92, filed on 1/7/2002, (33) U.S. provisional patent application serial no. 60/372,048, attorney docket no. 25791.93, filed on 4/12/2002, (34) U.S. provisional patent application serial no. 60/372,632, attorney docket no. 25791.101, filed on 4/15/2002, (35) U.S. provisional patent application serial no. 60/380,147, attorney docket no. 25791.104, filed on 5/6/2002, (36) U.S. provisional patent application serial no. 60/387,486, attorney docket no. 25791.107, filed on 6/10/2002, and (37) U.S. provisional patent application serial no. 60/387,961, attorney docket no. 25791.108, filed on 6/12/2002, the disclosures of which are incorporated herein by reference.

[004] This invention relates generally to oil and gas exploration, and in particular to forming and repairing wellbore casings to facilitate oil and gas exploration and production.

Background of the Invention

[005] Conventionally, when a wellbore is created, a number of casings are installed in the borehole to prevent collapse of the borehole wall and to prevent undesired outflow of drilling fluid into the formation or inflow of fluid from the formation into the borehole. The borehole is drilled in intervals whereby a casing which is to be installed in a lower borehole interval is lowered through a previously installed casing of an upper borehole interval. As a consequence of this procedure the casing of the lower interval is of smaller diameter than the casing of the upper interval. Thus, the casings are in a nested arrangement with casing diameters decreasing in downward direction. Cement annuli are provided between the outer surfaces of the casings and the borehole wall to seal the casings from the borehole wall. As a consequence of this nested arrangement a relatively large borehole diameter is required at the upper part of the wellbore. Such a large borehole diameter involves increased costs due to heavy casing handling equipment, large drill bits and increased volumes of drilling fluid and drill cuttings.

reover, increased drilling rig time is involved due to required cement pumping, cement hardening, required equipment changes due to large variations in hole diameters drilled in the course of the well, and the large volume of cuttings drilled and removed.

[006] The present invention is directed to overcoming one or more of the limitations of the existing processes for forming and repairing wellbore casings.

Summary of the Invention

According to the present invention, there is provided a method of radially expanding a tubular member, comprising:

positioning an expansion device within the tubular member;

defining an annulus between the expansion device and the interior surface of the tubular member;

displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member; and

during the displacement of the expansion device relative to the tubular member, injecting fluidic material through the expansion device into the annulus.

Preferably, the expansion device comprises an expansion cone comprising a tapered exterior surface and non-tapered exterior surfaces positioned above and below the tapered exterior surface;

wherein the annulus is defined between the tapered and non-tapered exterior surfaces of the expansion cone and the interior surface of the tubular member;

wherein displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member comprises:

displacing the expansion cone relative to the tubular member to radially expand and plastically deform the tubular member;

wherein during the displacement of the expansion device relative to the tubular member, injecting fluidic material through the expansion device into the annulus comprises:

during the displacement of the expansion cone relative to the tubular member, injecting the fluidic material through the non-tapered exterior surface of the expansion cone above the tapered exterior surface of the expansion cone into the annulus; and

wherein the method further comprises:

during the displacement of the expansion cone relative to the tubular member, conveying the fluidic material through the remaining length of the annulus.

Preferably, displacing the expansion cone relative to the tubular member comprises:

pulling the expansion cone through the tubular member using fluid pressure.

Preferably, pulling the expansion cone through the tubular member using fluid pressure comprises:

pressuring an annular chamber within the tubular member above the expansion cone.

Preferably, displacing the expansion cone relative to the tubular member comprises:

pushing the expansion cone through the tubular member using fluid pressure.

Preferably, pushing the expansion cone through the tubular member using fluid pressure comprises:

pressurizing a chamber within the tubular member below the expansion cone.

Preferably, the fluidic material is injected through the tapered exterior surface of the expansion cone into a portion of the annulus bounded by the tapered exterior surface.

Preferably, the fluidic material is injected through the non-tapered exterior surface of the expansion cone above the tapered exterior surface of the expansion cone and the tapered exterior surface of the expansion cone into a portion of the annulus above the tapered exterior surface and another portion of the annulus bounded by the tapered exterior surface.

Preferably, the expansion device comprises an exterior expansion surface;

wherein the annulus is defined between the exterior expansion surface of the expansion device and the interior surface of the tubular member; and

wherein the method further comprises:

during the displacement of the expansion device relative to the tubular member, conveying the fluidic material through the remaining length of the annulus.

Preferably, displacing the expansion device relative to the tubular member comprises:

pulling the expansion device through the tubular member using fluid pressure.

Preferably, pulling the expansion device through the tubular member using fluid pressure comprises:

pressuring an annular chamber within the tubular member above the expansion device.

Preferably, displacing the expansion device relative to the tubular member comprises:

pushing the expansion device through the tubular member using fluid pressure.

Preferably, pushing the expansion device through the tubular member using fluid pressure comprises:

pressurizing a chamber within the tubular member below the expansion device.

Preferably, the fluidic material is injected through the exterior expansion surface of the expansion device into a portion of the annulus bounded by the exterior expansion surface of the expansion device.

Preferably, displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member comprises:

displacing the expansion device relative to the tubular member in a first direction to radially expand and plastically deform the tubular member;

wherein the method further comprises:

during the displacement of the expansion device relative to the tubular member, conveying the fluidic material through the remaining length of the annulus in a second direction; and

wherein the first and second directions are opposite to one another.

Preferably, the expansion device comprises an expansion cone comprising a tapered exterior surface and non-tapered exterior surfaces positioned above and below the tapered exterior surface;

wherein the annulus is defined between the tapered and non-tapered exterior surfaces of the expansion cone and the interior surface of the tubular member;

wherein displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member comprises:

displacing the expansion cone relative to the tubular member to radially expand and plastically deform the tubular member;

wherein during the displacement of the expansion device relative to the tubular member, injecting the fluidic material through the expansion device into the annulus comprises:

during the displacement of the expansion cone relative to the tubular member, injecting the fluidic material through the non-tapered exterior surface of the expansion cone above the tapered exterior surface of the expansion cone into the annulus;

wherein the method further comprises:

during the displacement of the expansion cone relative to the tubular member, conveying the fluidic material through the remaining length of the annulus;

wherein displacing the expansion cone relative to the tubular member comprises pulling the expansion cone through the tubular member using fluid pressure; and

wherein pulling the expansion cone through the tubular member using fluid pressure comprises:

pressuring an annular chamber within the tubular member above the expansion cone.

Preferably, the expansion device comprises an expansion cone comprising a tapered exterior surface and non-tapered exterior surfaces positioned above and below the tapered exterior surface;

wherein the annulus is defined between the tapered and non-tapered exterior surfaces of the expansion cone and the interior surface of the tubular member;

wherein displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member comprises:

displacing the expansion cone relative to the tubular member to radially expand and plastically deform the tubular member;

wherein during the displacement of the expansion device relative to the tubular member, injecting the fluidic material through the expansion device into the annulus comprises:

during the displacement of the expansion cone relative to the tubular member, injecting the fluidic material through the non-tapered exterior surface of the expansion cone above the tapered exterior surface of the expansion cone into the annulus;

wherein the method further comprises:

during the displacement of the expansion cone relative to the tubular member, conveying the fluidic material through the remaining length of the annulus;

wherein displacing the expansion cone relative to the tubular member comprises:

pushing the expansion cone through the tubular member using fluid pressure; and

wherein pushing the expansion cone through the tubular member using fluid pressure comprises: pressurizing a chamber within the tubular member below the expansion cone.

Preferably, the fluidic material is injected through the tapered exterior surface of the expansion cone into a portion of the annulus bounded by the tapered exterior surface.

Preferably, the fluidic material is injected through non-tapered exterior surface of the expansion cone above the tapered exterior surface of the expansion cone and the tapered exterior surface of the expansion cone into a portion of the annulus above the tapered exterior surface and another portion of the annulus bounded by the tapered exterior surface.

Preferably, during the displacement of the expansion device relative to the tubular member, the annulus is pressurized in response to injecting the fluidic material through the expansion device into the annulus.

According to another aspect of the present invention, there is provided a system for radially expanding a tubular member, comprising:

means for positioning an expansion device within the tubular member;

means for defining an annulus between the expansion device and the interior surface of the tubular member;

means for displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member; and

during the displacement of the expansion device relative to the tubular member, means for injecting fluidic material through the expansion device into the annulus.

Preferably, means for positioning the expansion device within the tubular member comprises:

means for positioning an expansion cone within the tubular member; and

wherein means for displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member comprises:

means for displacing the expansion cone relative to the tubular member.

Preferably, means for displacing the expansion cone relative to the tubular member comprises:

means for pulling the expansion cone through the tubular member using fluid pressure.

Preferably, means for pulling the expansion cone through the tubular member using fluid pressure comprises:

means for pressuring an annular chamber within the tubular member above the expansion cone.

Preferably, means for displacing the expansion cone relative to the tubular member comprises:

means for pushing the expansion cone through the tubular member using fluid pressure.

Preferably, means for pushing the expansion cone through the tubular member using fluid pressure comprises:

means for pressurizing a chamber within the tubular member below the expansion cone.

Preferably, means for displacing the expansion device relative to the tubular member comprises:

means for pulling the expansion device through the tubular member using fluid pressure.

Preferably, means for pulling the expansion device through the tubular member using fluid pressure comprises:

means for pressuring an annular chamber within the tubular member above the expansion device.

Preferably, means for displacing the expansion device relative to the tubular member comprises:

means for pushing the expansion device through the tubular member using fluid pressure.

Preferably, means for pushing the expansion device through the tubular member using fluid pressure comprises:

means for pressurizing a chamber within the tubular member below the expansion device.

Preferably, the operating pressure of the chamber and the annulus are approximately equal.

Preferably, means for positioning the expansion device within the tubular member comprises:

means for positioning an expansion cone comprising a tapered exterior surface and non-tapered exterior surfaces positioned above and below the tapered exterior surface within the tubular member;

wherein means for defining the annulus between the expansion device and the interior surface of the tubular member comprises:

means for defining the annulus between the tapered and non-tapered exterior surfaces of the expansion cone and the interior surface of the tubular member;

wherein means for displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member comprises:

means for displacing the expansion cone relative to the tubular member to radially expand and plastically deform the tubular member;

wherein during the displacement of the expansion device relative to the tubular member, means for injecting the fluidic material through the expansion device into the annulus comprises:

during the displacement of the expansion cone relative to the tubular member, means for injecting the fluidic material through the non-tapered exterior surface of the expansion cone above the tapered exterior surface of the expansion cone into the annulus and conveying the fluidic material through the remaining length of the annulus;

wherein means for displacing the expansion cone relative to the tubular member comprises means for pulling the expansion cone through the tubular member using fluid pressure; and

wherein means for pulling the expansion cone through the tubular member using fluid pressure comprises: means for pressuring an annular chamber within the tubular member above the expansion cone.

Preferably, means for positioning the expansion device within the tubular member comprises:

means for positioning an expansion cone comprising a tapered exterior surface and non-tapered exterior surfaces positioned above and below the tapered exterior surface within the tubular member;

wherein means for defining the annulus between the expansion device and the interior surface of the tubular member comprises:

means for defining the annulus between the tapered and non-tapered exterior surfaces of the expansion cone and the interior surface of the tubular member;

wherein means for displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member comprises:

means for displacing the expansion cone relative to the tubular member to radially expand and plastically deform the tubular member;

wherein during the displacement of the expansion device relative to the tubular member, means for injecting the fluidic material through the expansion device into the annulus comprises:

during the displacement of the expansion cone relative to the tubular member, means for injecting the fluidic material through the non-tapered exterior surface of the expansion cone above the tapered exterior surface of the expansion cone into the annulus and conveying the fluidic material through the remaining length of the annulus;

wherein means for displacing the expansion cone relative to the tubular member comprises:

means for pushing the expansion cone through the tubular member using fluid pressure; and

wherein means for pushing the expansion cone through the tubular member using fluid pressure comprises: means for pressurizing a chamber within the tubular member below the expansion cone.

Preferably, the fluidic material is injected through the tapered exterior surface of the expansion cone into a portion of the annulus bounded by the tapered exterior surface.

Preferably, the fluidic material is injected through non-tapered exterior surface of the expansion cone above the tapered exterior surface of the expansion cone and the tapered exterior surface of the expansion cone into a portion of the annulus above the tapered exterior surface and another portion of the annulus bounded by the tapered exterior surface.

Brief Description of the Drawings

[007] Fig. 1 is a fragmentary cross-sectional illustration of the placement of an apparatus for radially expanding a tubular member within a borehole that traverses a subterranean formation.

[008] Figs. 2a and 2b are fragmentary cross-sectional illustrations of the apparatus of Fig. 1 after initiating the radial expansion and plastic deforming of the tubular member.

[009] Fig.3 is a graphical illustration of the unexpected result provided during the operation of the apparatus of Figs. 2a and 2b during the radial expansion and plastic deformation of the tubular member.

[0010] Fig. 4 is a fragmentary cross-sectional illustration of the apparatus of Figs. 2a and 2b after completing the radial expansion and plastic deformation of the tubular member.

Detailed Description of the Illustrative Embodiments

[0014] In an exemplary embodiment, as illustrated in Fig. 1, an apparatus 10 is positioned within a borehole 12 that traverses a subterranean formation 14 that may include a source of hydrocarbons and/or geothermal energy.

[0015] In an exemplary embodiment, the apparatus includes a tubular support member 16 that defines a longitudinal passage 16a. An upper end 18a of a tubular expansion cone 18 that defines a longitudinal passage 18b, radial passages, 18ca and 18cb, that extend from the longitudinal passage to the outer surface of the tubular expansion cone above a conical outer surface 18d, and radial passages, 18cc and 18cd, that extend from the longitudinal passage to the conical outer surface, is coupled to an end of the tubular support member 16. In this manner, fluidic materials may be conveyed from the passage 16a of the tubular support member 16 through the longitudinal passage 18b of the tubular expansion cone 18 and into the radial passages, 18ca, 18cb, 18cc, and 18cd, of the tubular expansion cone.

[0016] A tubular tapered expansion cone launcher 20 receives the outer conical surface 18d of the tubular expansion cone 18 within an interior passage 20a. In an exemplary embodiment, the interior surface of the tubular tapered expansion cone launcher 20 is a conical surface that is complementary shaped with respect to the outer conical surface 18d of the tubular expansion cone 18. An end of a tubular shoe 22 is coupled to an end of the tubular tapered expansion cone launcher 20 that defines an interior passage 22a an a valveable longitudinal passage 22b that may be adapted to receive a valve member such as, for example, a ball.

[0017] An end of an expandable tubular 24 that defines an internal passage 24a is coupled to another end of the tubular tapered expansion cone launcher 20. In an exemplary embodiment, the wall thickness of the expandable tubular 24 is greater than the wall thickness of the tubular tapered expansion cone launcher 20. In this manner, the initiation of the radial expansion of the expandable tubular member 24 is facilitated and the apparatus 10 may be positioned within wellbores 12 having tight radial clearances relative to the expansion cone launcher 20.

[0018] A resilient GuibersonJ sealing cup 26 is coupled to the exterior of the tubular support 16. In an exemplary embodiment, during operation of the apparatus 10, the sealing cup 26 engages the interior surface of the expandable tubular member 24 and thereby defines an annular chamber 28 between the exterior of the tubular support 16 and the interior of the expandable tubular member above the tubular expansion cone 18.

[0019] In an exemplary embodiment, as illustrated in Figs. 2a and 2b, during operation of the apparatus 10, a ball 30 is placed in the valveable passage 22b of the shoe 22 by injecting a fluidic material 32 into the apparatus 10 through the passages 16a and 18b. In this manner, the interior 22a of the tubular shoe 22 below the tubular expansion cone 18 and the annular chamber 28 above the tubular expansion cone below the GuibersonJ cup seal 26 may both be pressurized. In particular, continued injection of the fluidic material 32 into the apparatus 10

through the passages 16a and 18b will pressurize the interior of the tubular shoe 22 below the tubular expansion cone 18 as well as the annular chamber 28 above the tubular expansion cone below the GuibersonJ cup seal 26. As a result, the tubular expansion cone 18 will be displaced upwardly in the longitudinal direction relative to the tubular expansion cone launcher 20, the tubular shoe 22, and the expandable tubular member 24. In particular, the pressurization of the annular chamber 28 will cause the GuibersonJ cup seal 26 to pull the tubular expansion cone 18 upwardly out of the apparatus 10. Furthermore, the pressurization of the interior 22a of the tubular shoe 22 below the tubular expansion cone 18 will push the tubular expansion cone upwardly out of the apparatus 10. As a result, the tubular expansion cone launcher 20 and the expandable tubular member 24 are radially expanded and plastically deformed.

[0020] In an exemplary embodiment, during the radial expansion and plastic deformation of the tubular expansion cone launcher 20 and the expandable tubular member 24, the fluidic material 32 is conveyed through the radial passages, 18ca, 18cb, 18cc, and 18cd, into the annulus 34 defined between the conical exterior surface 18d of the tubular expansion cone 18 and the interior surfaces of the tubular expansion cone launcher 20 and/or the expandable tubular member 24. As an unexpected result, the tubular expansion cone launcher 20 and/or the expandable tubular member 24 hydroplane on the conical outer surface 18d of the tubular expansion cone 18 during the radial expansion and plastic deformation of the tubular expansion cone launcher and expandable tubular member. During exemplary experimental testing of the apparatus 10, the unexpected hydroplaning of the expansion cone launcher 20 and/or the expandable tubular member 24 hydroplane on the conical outer surface 18d of the tubular expansion cone 18 during the radial expansion and plastic deformation of the tubular expansion cone launcher and expandable tubular member provided the further unexpected result of reducing the operating pressure of the fluidic material 32 required to radially expand and plastically deform the tubular expansion cone launcher 20 and/or the expandable tubular member 24. In an exemplary experimental test of the apparatus 10, the operating pressure within the annulus 34 was approximately equal to the operating pressures within the apparatus 10 below the tubular expansion cone 18 and within the annular chamber 28.

[0021] As illustrated in Fig. 3, the curve 100 illustrates typical required operating pressures of the fluidic material 32 in order to radially expand and plastically deform the tubular expansion cone launcher 20 and/or the expandable tubular member 24 for a range of angles of attack of the conical outer surface 18d of the tubular expansion cone 18. As will be recognized by persons having ordinary skill in the art, the angle of the attack of the conical outer surface 18d of the tubular expansion cone 18 refers to the angle of inclination of the conical outer surface relative to the longitudinal direction. By contrast, the curve 102 illustrates typical required operating pressures of the fluidic material 32 in order to radially expand and plastically deform the expandable tubular member 24 for a range of angles of attack of the conical outer surface

of the tubular expansion cone 18 where the radial passages, 18ca, 18cb, 18cc, and 18cd, were omitted from the tubular expansion cone. Unexpectedly, the omission of the radial passages, 18ca, 18cb, 18cc, and 18cd, from the tubular expansion cone 18 of the apparatus 10 significantly increased the required operating pressures of the fluidic material 32 in order to radially expand and plastically deform the expandable tubular member 24 across the range of angles of attack of the conical outer surface 18d of the tubular expansion cone 18. Thus, the unexpected hydroplaning of the expansion cone launcher 20 and the expandable tubular member 24 hydroplane on the conical outer surface 18d of the tubular expansion cone 18 during the radial expansion and plastic deformation of the tubular expansion cone launcher and expandable tubular member provided the further unexpected result of reducing the operating pressure of the fluidic material 32 required to radially expand and plastically deform the tubular expansion cone launcher and/or the expandable tubular member.

[0019] In an exemplary embodiment, as illustrated in Fig. 4, after completing the radial expansion and plastic deformation of the tubular expansion cone launcher 20 and the expandable tubular member 24, the expandable tubular member is coupled to the interior surface of the borehole 12.

[0020] It is understood that variations may be made in the foregoing without departing from the scope of the invention. For example, the teachings of the present illustrative embodiments may be used to provide a wellbore casing, a pipeline, or a structural support. Furthermore, the elements and teachings of the various illustrative embodiments may be combined in whole or in part in some or all of the illustrative embodiments. In addition, the tubular expansion cone 18 may include one or more radial passages 18c extending from the longitudinal passage 18b to the exterior surface of the tubular expansion cone. Furthermore, the apparatus may include one or more GuibersonJ cup seals 26.

[0021] Although illustrative embodiments of the invention have been shown and described, a wide range of modification, changes and substitution is contemplated in the foregoing disclosure. Accordingly, it is appropriate that the appended claims be construed broadly.

CLAIMS

1. A method of radially expanding a tubular member, comprising:

positioning an expansion device within the tubular member;

defining an annulus between the expansion device and the interior surface of the tubular member;

displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member; and

during the displacement of the expansion device relative to the tubular member, injecting fluidic material through the expansion device into the annulus.

2. The method of claim 1, wherein the expansion device comprises an expansion cone comprising a tapered exterior surface and non-tapered exterior surfaces positioned above and below the tapered exterior surface;

wherein the annulus is defined between the tapered and non-tapered exterior surfaces of the expansion cone and the interior surface of the tubular member;

wherein displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member comprises:

displacing the expansion cone relative to the tubular member to radially expand and plastically deform the tubular member;

wherein during the displacement of the expansion device relative to the tubular member, injecting fluidic material through the expansion device into the annulus comprises:

during the displacement of the expansion cone relative to the tubular member, injecting the fluidic material through the non-tapered exterior surface of the expansion cone above the tapered exterior surface of the expansion cone into the annulus; and

wherein the method further comprises:

during the displacement of the expansion cone relative to the tubular member, conveying the fluidic material through the remaining length of the annulus.

3. The method of claim 2, wherein displacing the expansion cone relative to the tubular member comprises:

pulling the expansion cone through the tubular member using fluid pressure.

4. The method of claim 3, wherein pulling the expansion cone through the tubular member using fluid pressure comprises:

pressuring an annular chamber within the tubular member above the expansion cone.

5. The method of claim 2, wherein displacing the expansion cone relative to the tubular member comprises:

pushing the expansion cone through the tubular member using fluid pressure.

6. The method of claim 5, wherein pushing the expansion cone through the tubular member using fluid pressure comprises:

pressurizing a chamber within the tubular member below the expansion cone.

7. The method of claim 2, wherein the fluidic material is injected through the tapered exterior surface of the expansion cone into a portion of the annulus bounded by the tapered exterior surface.

8. The method of claim 2, wherein the fluidic material is injected through the non-tapered exterior surface of the expansion cone above the tapered exterior surface of the expansion cone and the tapered exterior surface of the expansion cone into a portion of the annulus above the tapered exterior surface and another portion of the annulus bounded by the tapered exterior surface.

9. The method of claim 1, wherein the expansion device comprises an exterior expansion surface;

wherein the annulus is defined between the exterior expansion surface of the expansion device and the interior surface of the tubular member; and

wherein the method further comprises:

during the displacement of the expansion device relative to the tubular member, conveying the fluidic material through the remaining length of the annulus.

10. The method of claim 9, wherein displacing the expansion device relative to the tubular member comprises:

pulling the expansion device through the tubular member using fluid pressure.

11. The method of claim 10, wherein pulling the expansion device through the tubular member using fluid pressure comprises:

pressuring an annular chamber within the tubular member above the expansion device.

12. The method of claim 9, wherein displacing the expansion device relative to the tubular member comprises:

pushing the expansion device through the tubular member using fluid pressure.

13. The method of claim 12, wherein pushing the expansion device through the tubular member using fluid pressure comprises:

pressurizing a chamber within the tubular member below the expansion device.

14. The method of claim 9, wherein the fluidic material is injected through the exterior expansion surface of the expansion device into a portion of the annulus bounded by the exterior expansion surface of the expansion device.

15. The method of claim 1, wherein displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member comprises:

displacing the expansion device relative to the tubular member in a first direction to radially expand and plastically deform the tubular member;

wherein the method further comprises:

during the displacement of the expansion device relative to the tubular member, conveying the fluidic material through the remaining length of the annulus in a second direction; and

wherein the first and second directions are opposite to one another.

16. The method of claim 1, wherein the expansion device comprises an expansion cone comprising a tapered exterior surface and non-tapered exterior surfaces positioned above and below the tapered exterior surface;

wherein the annulus is defined between the tapered and non-tapered exterior surfaces of the expansion cone and the interior surface of the tubular member;

wherein displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member comprises:

displacing the expansion cone relative to the tubular member to radially expand and plastically deform the tubular member;

wherein during the displacement of the expansion device relative to the tubular member, injecting the fluidic material through the expansion device into the annulus comprises:

during the displacement of the expansion cone relative to the tubular member, injecting the fluidic material through the non-tapered exterior surface of the expansion cone above the tapered exterior surface of the expansion cone into the annulus;

wherein the method further comprises:

during the displacement of the expansion cone relative to the tubular member, conveying the fluidic material through the remaining length of the annulus;

wherein displacing the expansion cone relative to the tubular member comprises pulling the expansion cone through the tubular member using fluid pressure; and

wherein pulling the expansion cone through the tubular member using fluid pressure comprises:

pressuring an annular chamber within the tubular member above the expansion cone.

17. The method of claim 1, wherein the expansion device comprises an expansion cone comprising a tapered exterior surface and non-tapered exterior surfaces positioned above and below the tapered exterior surface;

wherein the annulus is defined between the tapered and non-tapered exterior surfaces of the expansion cone and the interior surface of the tubular member;

wherein displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member comprises:

displacing the expansion cone relative to the tubular member to radially expand and plastically deform the tubular member;

wherein during the displacement of the expansion device relative to the tubular member, injecting the fluidic material through the expansion device into the annulus comprises:

during the displacement of the expansion cone relative to the tubular member, injecting the fluidic material through the non-tapered exterior surface of the expansion cone above the tapered exterior surface of the expansion cone into the annulus;

wherein the method further comprises:

during the displacement of the expansion cone relative to the tubular member, conveying the fluidic material through the remaining length of the annulus;

wherein displacing the expansion cone relative to the tubular member comprises:

pushing the expansion cone through the tubular member using fluid pressure; and

wherein pushing the expansion cone through the tubular member using fluid pressure comprises: pressurizing a chamber within the tubular member below the expansion cone.

18. The method of claim 1 or 17, wherein the fluidic material is injected through the tapered exterior surface of the expansion cone into a portion of the annulus bounded by the tapered exterior surface.

19. The method of claim 1 or 17, wherein the fluidic material is injected through non-tapered exterior surface of the expansion cone above the tapered exterior surface of the expansion cone and the tapered exterior surface of the expansion cone into a portion of the annulus above the tapered exterior surface and another portion of the annulus bounded by the tapered exterior surface.

20. The method of claim 1 wherein during the displacement of the expansion device relative to the tubular member, the annulus is pressurized in response to injecting the fluidic material through the expansion device into the annulus.

21. A system for radially expanding a tubular member, comprising:

means for positioning an expansion device within the tubular member;

means for defining an annulus between the expansion device and the interior surface of the tubular member;

means for displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member; and

during the displacement of the expansion device relative to the tubular member,

means for injecting fluidic material through the expansion device into the annulus.

22. The system of claim 21, wherein means for positioning the expansion device within the tubular member comprises:

means for positioning an expansion cone within the tubular member; and

wherein means for displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member comprises:

means for displacing the expansion cone relative to the tubular member.

23. The system of claim 22 wherein means for displacing the expansion cone relative to the tubular member comprises:

means for pulling the expansion cone through the tubular member using fluid pressure.

24. The system of claim 23, wherein means for pulling the expansion cone through the tubular member using fluid pressure comprises:

means for pressuring an annular chamber within the tubular member above the expansion cone.

25. The system of claim 22, wherein means for displacing the expansion cone relative to the tubular member comprises:

means for pushing the expansion cone through the tubular member using fluid pressure.

26. The system of claim 25, wherein means for pushing the expansion cone through the tubular member using fluid pressure comprises:

means for pressurizing a chamber within the tubular member below the expansion cone.

27. The system of claim 21, wherein means for displacing the expansion device relative to the tubular member comprises:

means for pulling the expansion device through the tubular member using fluid pressure.

28. The system of claim 27, wherein means for pulling the expansion device through the tubular member using fluid pressure comprises:

means for pressuring an annular chamber within the tubular member above the expansion device.

29. The system of claim 21, wherein means for displacing the expansion device relative to the tubular member comprises:

means for pushing the expansion device through the tubular member using fluid pressure.

30. The system of claim 29, wherein means for pushing the expansion device through the tubular member using fluid pressure comprises:

means for pressurizing a chamber within the tubular member below the expansion device.

31. The system of claim 30, wherein the operating pressure of the chamber and the annulus are approximately equal.

32. The system of claim 21, wherein means for positioning the expansion device within the tubular member comprises:

means for positioning an expansion cone comprising a tapered exterior surface and non-tapered exterior surfaces positioned above and below the tapered exterior surface within the tubular member;

wherein means for defining the annulus between the expansion device and the interior surface of the tubular member comprises:

means for defining the annulus between the tapered and non-tapered exterior surfaces of the expansion cone and the interior surface of the tubular member;

wherein means for displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member comprises:

means for displacing the expansion cone relative to the tubular member to radially expand and plastically deform the tubular member;

wherein during the displacement of the expansion device relative to the tubular member, means for injecting the fluidic material through the expansion device into the annulus comprises:

during the displacement of the expansion cone relative to the tubular member, means for injecting the fluidic material through the non-tapered exterior surface of the expansion cone above the tapered exterior surface of the expansion cone into the annulus and conveying the fluidic material through the remaining length of the annulus;

wherein means for displacing the expansion cone relative to the tubular member comprises means for pulling the expansion cone through the tubular member using fluid pressure; and

wherein means for pulling the expansion cone through the tubular member using fluid pressure comprises: means for pressuring an annular chamber within the tubular member above the expansion cone.

33. The system of claim 21, wherein means for positioning the expansion device within the tubular member comprises:

means for positioning an expansion cone comprising a tapered exterior surface and non-tapered exterior surfaces positioned above and below the tapered exterior surface within the tubular member;

wherein means for defining the annulus between the expansion device and the interior surface of the tubular member comprises:

means for defining the annulus between the tapered and non-tapered exterior surfaces of the expansion cone and the interior surface of the tubular member;

wherein means for displacing the expansion device relative to the tubular member to radially expand and plastically deform the tubular member comprises:

means for displacing the expansion cone relative to the tubular member to radially expand and plastically deform the tubular member;

wherein during the displacement of the expansion device relative to the tubular member, means for injecting the fluidic material through the expansion device into the annulus comprises:

during the displacement of the expansion cone relative to the tubular member, means for injecting the fluidic material through the non-tapered exterior surface of the expansion cone above the tapered exterior surface of the expansion cone into the annulus and conveying the fluidic material through the remaining length of the annulus;

wherein means for displacing the expansion cone relative to the tubular member comprises:

means for pushing the expansion cone through the tubular member using fluid pressure; and

wherein means for pushing the expansion cone through the tubular member using fluid pressure comprises: means for pressurizing a chamber within the tubular member below the expansion cone.

34. The system of claim 32 or 33, wherein the fluidic material is injected through the tapered exterior surface of the expansion cone into a portion of the annulus bounded by the tapered exterior surface.

35. The system of claim 32 or 33, wherein the fluidic material is injected through non-tapered exterior surface of the expansion cone above the tapered exterior surface of the expansion cone and the tapered exterior surface of the expansion cone into a portion of the annulus above the tapered exterior surface and another portion of the annulus bounded by the tapered exterior surface.